# EFFECTS OF PLANTATIONS AND HOME-GARDENS ON TROPICAL FOREST BIRD COMMUNITIES AND MIXED-SPECIES BIRD FLOCKS IN THE SOUTHERN WESTERN GHATS

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Conservation scientists and policy makers are increasingly aware of the role countryside habitats play in supporting tropical fauna in modern landscapes. We studied the value of different land-uses by examining composition of tropical bird communities and mixed-species bird flocks in human-altered landscapes of Thattekad and the Anamalai Hills, situated in two different altitudes, in the southern Western Ghats. Sixteen line transects distributed across tropical rainforests, shade plantations of coffee and cardamom, timber monocultures of teak, tea plantations, and home-gardens were surveyed for bird flocks, vegetation structure, foliage profile, and canopy attributes. Results indicate that tea plantations were extremely altered habitats, supporting few rainforest species and were devoid of mixed-species bird flocks. Teak monocultures had high species density but were less conducive for rainforest species that require a well-developed and structurally more complex habitat. While bird species richness varied little across land-uses, there was significant variation in community composition, with some sensitive bird species absent from all altered habitats. Coffee plantations with surviving rainforest fragments and cardamom plantations with more native shade trees that mimicked a forest habitat supported more rainforest bird species both in communities and flocks. Maintenance of these shade plantations and restoration of forest fragments is recommended, while their conversion into a poor, more open habitat (tea, teak) is strongly discouraged for bird conservation in fragmented landscapes.

**Key words**: land-use changes, countryside habitat, Rainforest bird community, mixed-species bird flocks, southern Western Ghats

## INTRODUCTION

Globally, deforestation continues to threaten tropical rainforests (Wright and Muller-Landau 2006) that are believed to contain two-thirds of the world's plant and animal species (Raven 1988). Current threats to the rainforests include habitat loss and degradation due to developmental activities, logging, conversion to agriculture and various monoculture plantations (DeFries *et al.* 2005), which leads to fragmentation and isolation of the remnant forest tracts (Laurance and Bierregaard 1997). In addition, land-use pressures in the tropics are impinged upon by high population growth rates and poverty in these regions (Bhagwat *et al.* 2008). Such threats are believed to disrupt ecological processes by way of affecting native forest communities (Koh *et al.* 2004; Sodhi *et al.* 2008).

For high population regions of the world, huge patches of primary forests cannot always be conserved as protected areas (Thiollay 1995). The role and protection of human-modified landscapes becomes extremely important in such cases. Countryside habitats, as they are called, include managed plantations, agricultural land, home-gardens, fallows, and forest remnants (Daily *et al.* 2001). A land-use providing sufficient shade tree cover, habitat connectivity, and supplementary native food resources surrounding a protected forest can increase the conservation potential of remnant forest habitats by supporting larger populations of animal species (Laurance *et al.* 2002; DeFries *et al.* 2005; Raman 2006; Sekercioglu *et al.* 2006; Bhagwat *et al.* 2008).

Effects of habitat fragmentation or degradation on bird communities are well-researched. Studies have shown species richness and abundance to decrease with more intensive management of agroforests (Thiollay 1995; Scales and Marsden 2008) with higher extinction rates of forest dependent avifauna as a consequence of deforestation (Brooks *et al.* 1997; Castelletta *et al.* 2000). Deforestation affects occupancy dynamics of bird species by forest area reduction and isolation of remaining patches (Ferraz *et al.* 2007). Waltert *et al.* (2005) stressed the importance of over-storey tree density in tropical land-use systems for maintenance of resident forest bird populations and found natural forests to be important for bird conservation more than any other form of forest exploitation. Studies also show a great proportion of native forest species to survive in the countryside with potential for species movement between forest habitats, thus emphasizing the importance of such habitats (Greenberg *et* *al.* 1997; Hughes *et al.* 2002; Bhagwat *et al.* 2008; Ranganathan *et al.* 2008).

Along with studying bird communities of agrosystems, social interactions between species such as 'mixed-species bird flocks' (Buskirk 1976; Morse 1977), referred to as flocks hereafter, must also be considered. The influence of forest degradation on social interactions among birds such as flocks, although well-studied in Neotropics (Stouffer and Bierregaard 1995; Maldonado-Coelho and Marini 2004), remains poorly understood in the tropical rainforests of Asia (but see Lee *et al.* 2005; Sridhar and Sankar 2008). Flocks are known to have high species participation, hold territories and exist year-round, which makes them vulnerable to disturbances caused by fragmentation (Munn and Terborgh 1979; Thiollay 1994). It is important to assess the ability of different land-uses to support native bird communities and flocks to determine the relative conservation potential of various land-uses. This is needed to plan habitat and landscape management that strives for a balance between economic and ecological needs.

The Western Ghats hill range of India is among the global biodiversity hotspots (Myers *et al.* 2000) and is also recognised as an Endemic Bird Area (Stattersfield *et al.* 1998). This region has been severely modified by humans historically, with the middle and higher elevations altered into a mosaic of disturbance regimes containing forest fragments of varying size, habitat-quality, and degree of isolation, interspersed among monoculture plantations of timber trees such as alien *Eucalyptus* sp. or native teak (*Tectona grandis*), plantations of coffee (*Coffea arabica*, *C. canephora*) and cardamom (*Elettaria cardamomum*) with shade trees, and tea plantations with hardly any shade left (Congreve 1942; Nair 1991; Mudappa and Raman 2007).

Studies from the Western Ghats have demonstrated how bird communities vary in different types of plantations in relation to characteristics such as habitat structure, distance from forest, and proportion of native or alien tree species (Pramod *et al.* 1997; Bhagwat *et al.* 2005; Raman 2006; Bhagwat *et al.* 2008; Ranganathan *et al.* 2008). In the southern Western Ghats, earlier studies looking at the effects of habitat fragmentation in this region focused on differences in bird community structure and flock composition among fragments of varying sizes and isolation (Raman 2001; Sridhar and Sankar 2008). However, survival of bird species in fragments also depends on quality of the land-use matrix around these fragments (Gascon *et al.* 1999; Stouffer *et al.* 2006; Raman 2006), and therefore, it is important to study this matrix's effectiveness to support forest bird species.

We studied changes in bird communities and flocks of the southern Western Ghats along a habitat gradient from relatively undisturbed forests to plantations with varying agricultural intensities situated at two altitude zones in the southern Western Ghats. In order to understand changes in bird community structure and flock composition, size, and density along a gradient of land-use types, we formulated the following key questions

1. How is the habitat structure different in different land-uses?

2. Does bird community structure and composition change in relation to land-use and habitat structure?

3. Does flock encounter rate, size, and composition change in relation to land-use and habitat structure?

We use the results to assess the relative impact of various land-use types on bird conservation and management in the southern Western Ghats.

## STUDY AREA

This study was carried out at two sites, namely Thattekad and Anamalai Hills, in the southern Western Ghats. The southern Western Ghats is the region south of the Palghat Gap at 11° N in the Western Ghats, a 1,600 km long hill chain running parallel to India's west coast from 8° N to 21° N (Mani 1974; Pascal 1988).

The Thattekad site (10° 10'-10° 15' N, 76° 65'-76° 78' E) is comprised of Thattekad Bird Sanctuary and Malayatoor Reserved Forest. The 25.16 sq. km bird sanctuary spans an altitudinal range of 50-250 m and is bordered by Periyar and Kuttampuzha rivers on two sides. Two-thirds of its area is under teak and mahogany plantations, with the rest containing disturbed tropical evergreen, semi-evergreen, and moist deciduous forests, *Ochlandra travancorica* reed brakes, grasslands with rock outcrops, and human-settlements (Sugathan and Vargheese 1996). The Reserved Forest in Malayatoor has disturbed tropical semi-evergreen forest and teak plantations. The mean annual rainfall is around 3,000 mm, three-fourths of which falls during south-west monsoon (Sugathan and Vargheese 1996).

The Anamalai Hills are a major conservation area in the southern Western Ghats (Raman 2006). The study sites here were concentrated on the Valparai plateau and Vazhachal Forest division (10° 27'-10° 35' N, 76° 82'-76° 90' E), adjoining the Anamalai Tiger Reserve and Parambikulam Wildlife Sanctuary. The altitude varies between 800 m and 1,100 m above sea level. The natural vegetation of this region, classified as tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type receives a mean annual rainfall of around 3,500 mm, particularly during south-west monsoon between June and September (Pascal 1988). The Valparai plateau contains 220 sq. km of tea, coffee, and cardamom plantations surrounded by protected areas and reserved forests (Mudappa and Raman 2007). Vazhachal is a Reserved Forest adjoining the Valparai plateau with intervening tribal settlement, coffee and tea plantations, and an inter-state road passing through.

## METHODOLOGY

### Transects and stratification

Tropical bird communities are difficult to sample and in order to maximize our effort on the time spent sampling we used line transects (Karr 1981; Whitman *et al.* 1997; Thiollay 1999). The line transect method was also chosen so as to obtain a reasonable sample of flocks along with data on bird communities. Eight transects were laid in each study site (see description of transects in Table 1) and were identified based on preliminary surveys in 2007. All transects were around 2 km long (except TFC, 1.5 km length) and were >250 m from one another. Transects were grouped under three broad strata:

**Table 1**: Description of all transects in study sites

| Site | Strata | Code / Location | Description |
|---|---|---|---|
| **Thattekad** | Forest | TFA, Thattekad Bird Sanctuary | Transect on tar-road with low elevation evergreen forest on either side; disturbed due to firewood collection. |
| | | TFB, Thattekad Bird Sanctuary | Transect along a footpath and forest trail; forest encompasses rocky outcrops and bamboo clumps; disturbed due to firewood and bamboo collection. |
| | | TFC, Malayatoor Reserved Forest | Transect on a forest trail; runs very close to a river on one side for at least one-third the length. |
| | Buffer | TBA, Thattekad Bird Sanctuary (Teak Plantation) | Transect on a dirt road passing through teak plantation, evergreen forest with proximity to a river. |
| | | TBB, Thattekad Bird Sanctuary (Teak Plantation) | Transect on dirt road passing through teak plantation with proximity to a water body. Some native vegetation present but heavily disturbed; understorey is dense shrubby to open. |
| | | TBC, Malayatoor Reserved Forest (Teak Plantation) | Transect on a tar-road with much vehicular movement; teak buffer with some riverine vegetation in certain places and other trees, mostly *Bombax* sp.; a small stream cutting through the transect; abuts the Reserved Forest having disturbed evergreen vegetation and bamboo clumps. |
| | Village | TVA, Thattekad Bird Sanctuary (Home-garden) | Transect on tar-road with heavy traffic; human habitation with mostly home gardens having jackfruit, coconut, cocoa, coffee, and rubber (*Hevea* sp.) plantations. |
| | | TVB, Thattekad Bird Sanctuary (Home-garden) | Transect on tar-road and on footpath; tribal village with home gardens having rubber, pineapple, jackfruit, coconut, *Ailanthus malabaricus*, and Areca nut plantations. |
| **Anamalai Hills** | Forest | VFA, Vazhachal Reserved Forest | Transect on tar-road; around 400 × 50 sq. m of forest cut for power line along road; firewood collection but mature rainforest vegetation; a reservoir 200 m away and parallel to the transect line. |
| | | VFB, Vazhachal Reserved Forest | Transect on tar-road; mature rainforest vegetation; wider openings for power line than VFA with clearings along road sides. |
| | | VFC, Indira Gandhi Wildlife Sanctuary | Transect on tar-road; forest relatively undisturbed; 200 × 50 sq. m of forest with bamboo and canopy openings. |
| | Buffer | VBA, Vazhachal (Malakkiparai Coffee Plantation) | Transect on tar-road; coffee plantation with mix of exotic and native shade trees; has interspersed rainforest fragments. |
| | | VBB, Valparai (Uralikkal Coffee Plantation) | 850 m of transect line passing through dirt road and rest on tar-road; coffee plantation with mostly exotic shade trees; has interspersed rainforest fragments and a Eucalyptus plantation. |
| | | VBC, Valparai (Surulimalai Cardamom Plantation) | Transect on dirt road; cardamom plantation with native shade trees; also has 250 × 50 sq. m of coffee plantation under native shade trees. |
| | Village | VVA, Valparai (Malakkiparai Tea Plantation) | Transect line on a footpath; tea plantation with very sparse shade of alien tree, Silver Oak *Grevillea robusta*. |
| | | VVB, Valparai (Uralikkal Tea Plantation) | Transect line on a footpath; tea plantation with very sparse shade alien tree, Silver Oak *Grevillea robusta*. |

A, B, C represent replicates in particular strata

Fig. 1(a-f): Pictures representing the land-use surveyed during this study (clockwise from top left): a. relatively undisturbed rainforest, b. cardamom plantation, c. coffee plantation, d. teak monoculture, e. home-garden, f. tea plantation

i. forest: relatively undisturbed or moderately disturbed mature native forest vegetation in Thattekad and the Anamalai Hills.

ii. buffer: land-use of relatively moderate intensity represented by plantations with substantial tree cover such as teak monocultures in Thattekad and shade-coffee, and shade-cardamom plantations in the Anamalai Hills.

iii. village: intensive agricultural areas with human-habitations having little or highly altered tree cover as represented by home gardens in Thattekad and tea plantations in the Anamalai Hills (Table 1, Fig. 1).

Many transects were on tar-roads, seldom more than 3 m wide; few had occasional clearings along roadsides. The effects of roads on bird abundance vary with bird species, road type, season, and distance from the road (Develey and Stouffer 2001). The results reported, therefore, can be considered as a conservative measure of actual bird richness or abundance.

**Vegetation sampling**

Point-centred quarter method (PCQ, Krebs 1989) was used for collecting data on basal area and density of trees greater than 30 cm girth at breast height (GBH) with 15-20 points sampled per transect. The points were distributed at 100 m intervals along each transect line and located 10-15 m away from the line with consecutive samples placed alternating on the left and right side. As it was not possible to obtain PCQ data on one transect TVA, because it entailed entering houses and private property; we counted trees in quadrats visually estimated from the line to be 5 m × 5 m at every 100 m. The GBH of these trees could not be recorded. Shrub density was measured by counting all shrubs taller than 30 cm in height inside a 2 m × 2 m quadrat at every PCQ point. Other vegetation parameters measured were canopy height, canopy cover, canopy overlap, and vertical stratification (Raman *et al.* 1998; Raman and Sukumar 2002). These were collected at 40 points, located 50 m apart (37 m apart for TFC) along the transect line, with 20 points (15 for TFC) being away from the transect corresponding to PCQ plots and the rest on edge of the transect line so as to include effect of clearings of canopy along roads and footpaths. Canopy height estimation was practiced using a broken branch of known length and flipping it visually in air factoring the visual effect of distance away from the observer. Canopy cover was measured using a spherical densiometer. Canopy overlap above the transect was ranked from 0 to 3; 0 for no canopy directly overhead; 1 when there were branches or foliage overhead but they did not meet; 2 when the branches or foliage met but the sky was still visible through them; and 3 when the sky was no longer visible through the overhead foliage. Vertical stratification (distribution of foliage at different vertical levels) was assessed by recording presence of foliage in height classes (in metres) of 0-1, 1-2, 2-4, 4-8, 8-16, 16-24, 24-32, and >32 m in an imaginary vertical cylinder of 0.5 m radius around the observer.

**Bird and flock sampling**

SS spent five weeks to familiarize with bird identification, calls, songs, and distance estimation prior to onset of data collection. Data on bird communities and flocks were gathered from January to May 2008, spanning winter and breeding season when both migrants and residents were present in the study area. All transects were walked four times except VFA which was walked five times. Effort was made to walk the line transects at a consistent steady pace and to finish it more or less in two hours time. All birds seen or heard were recorded with an estimated distance of the bird from the observer in different distance classes in metres: 0-5, 5-10, 10-15, 15-20, 20-30, 30-50, 50-100, 100-150, and >150 m; size of the class becoming bigger as distance increases from the observer. Birds flying overhead or detected on the transect line were grouped under distance category 0. Birds were observed using 8 × 42 Nikon binoculars with a 6.3° field of vision and identified using Grimmett *et al.* 1998. All birds were noted under the distance category where they were first detected.

A flock was defined as an association of individuals of a minimum two bird species moving together for more than 5 minutes. We do not include bird aggregations such as those formed on fruiting trees. Whenever a mixed-species flock was encountered, it was observed for as long as it was visible up to a maximum of 30 minutes, after which transect survey continued at usual pace. All birds seen or heard in a flock were recorded within the same distance category as estimated for the first bird seen or identified. Transect were surveyed between 06:30 hrs and 11:30 hrs, but were usually finished within two hours of the starting time. Time spent on transects varied, with the average time spent per transect being 103 minutes. Surveying village transects took less time due to paucity of birds, whereas sites took longer to survey when more flocks or a large flock were encountered.

**Data analysis**

We used the ecological software KREBSWIN (Krebs 1989) to estimate mean tree density and basal area from PCQ data and corresponding standard errors for each transect. For each point on a transect the number of vertical classes (0-8) with foliage were added up to calculate vertical stratification. This number was averaged for all 40 points to produce an index of vertical stratification for a transect. The coefficient of variation of this index was used to represent habitat heterogeneity (Raman *et al.* 1998).

To calculate distribution of foliage in a specific vertical class along an entire transect, the presence-absence data on foliage in that vertical class was pooled for the transect across all 40 sampled points to yield a percentage value, and these percentages were arcsine transformed before statistical analysis. Means and standard errors of canopy cover, canopy overlap, and canopy height were estimated from replicate measurements in each transect.

To look for statistically significant differences in vegetation among sites (Thattekad and Anamalai Hills) and strata (forest, buffer, and village) we conducted a 2-factor Analysis of Variance (ANOVA) with site and strata as fixed factors. Due to correlations among eight vegetation variables considered, the vegetation data were summarized using Principal Components Analysis (PCA) into two uncorrelated factors. The analysis was performed using SPSS/PC+ software version 14.0, SPSS Inc., Chicago (Bryman and Cramer 1997). The factor matrix was rotated using Varimax method to aid in interpretation. The composition of trees on TVA was very similar to that on TVB and therefore for analysis we used the same basal area estimates of TVB for TVA in the PCA (see section 2.3).

All recorded bird species were classified into rainforest and open-forest species (Ali and Ripley 1983; Grimmett *et al.* 1998; Raman 2006). Rainforest birds were those that occurred naturally in undisturbed rainforests, whereas open-forest species were those that occurred in drier, more open habitats along the Western Ghats. Water birds were excluded from analysis. Bird community variables of interest were: bird species richness and bird species abundance estimated separately for all, rainforest species, and open-forest species. Individual-based rarefaction analysis was performed for overall bird species richness for standardized number of individuals using program ECOSIM (Gotelli and Colwell 2001). We also estimated bird species density (following terminology of Gotelli and Colwell 2001) as the average number of bird species per transect and bird species abundance as the number of individuals per transect (both separately for all, rainforest species, and open-forest species). Differences in bird species density and abundance (values averaged across repeat surveys) were assessed by 2-factor analysis of variance with site and strata as factors (Zar 1999).

To measure variation in bird community composition among various transects, we used Program PRIMER (version 5.2.2, Primer-E, Plymouth, UK; Clarke and Gorley 2001) to compute a pair-wise matrix of Bray-Curtis dissimilarity. This was used for non-metric Multi-dimensional Scaling (MDS) ordination to represent bird community compositional variation among transects. Significance of variation in community composition was assessed using Analysis of Similarities (ANOSIM) with a 2-factor crossed layout of sites and strata (Clarke and Warwick 1994).

Flocks were categorized as complete flocks (with total count of all participant species and individuals) and incomplete flocks (all individuals were not visible or could not be counted before the flock moved away or was lost). Flock variables of interest were: number of species and individuals participating in flocks of all, rainforest, and open-forest species. Only data from complete flocks were used for analyses. Differences in the number of species and individuals in complete flocks (values averaged across replicate flocks) were assessed by 2-factor analysis of variance with site and strata as factors (Zar 1999). Tea plantations were devoid of flocks during the survey period, and only two incomplete flocks were encountered in home-gardens. Therefore, we do not include village transects for analysis. We also calculated flock encounter rate as the number of flocks encountered per transect for all transects surveyed.

The effects of habitat structure on bird community and flock structure was assessed using multiple regression with PCA factor scores taken as independent variables representing habitat structure in the analyses. Dependent variables used were (for all, rainforest, and open forest species, separately) the number of bird species per transect, number of individuals per transect, species per complete flock, and individuals per complete flock. All analyses were performed using SPSS software with a backward stepwise procedure for selection of statistically significant effects (Zar 1999).

## RESULTS

### Variation in habitat structure of different land-uses

Distribution of foliage in different vertical categories differed markedly with land-use type. In the Thattekad site, two-factor analysis of variance (ANOVA) revealed statistically significant differences across the three habitat strata ($F_{2,40} = 34.07$, $P < 0.001$), as well as eight vertical layers ($F_{7,40} = 37.95$, $P < 0.001$), with a statistically significant interaction between the two factors ($F_{14,40} = 2.60$, $P < 0.01$). The percentage foliage distribution in different vertical categories in teak plantations and village transects was mostly lower when compared with forest transects. There was hardly any foliage above 32 m in teak plantation and above 24 m in village home gardens. In the Anamalai Hills, similarly, there were statistically significant differences across the three strata ($F_{2,40} = 159.2$, $P < 0.001$), as well as eight vertical layers ($F_{7,40} = 28.9$, $P < 0.001$), with a statistically significant interaction between the two factors ($F_{14,40} = 7.87$, $P < 0.001$). The coffee and cardamom plantations in Valparai had poor foliage distribution between 1-2 m, 2-4 m, 4-8 m and 8-16 m when compared with forest transects here. These transects, especially cardamom, had comparable foliage to forests in higher canopy above 16 m. Tea plantations almost always had some foliage on ground and some foliage in 16-24 m category. There was hardly any foliage in-between these two categories or above 24 m.

Other vegetation features also differed in relation to site and land-use (2-factor ANOVA, Table 2). All variables showed statistically significant differences across strata, whereas tree density, canopy cover, canopy overlap, and shrub density showed statistically significant differences across sites as well. Besides canopy height, shrub density, and habitat heterogeneity, other variables also showed a statistically significant interaction between site and strata (Table 2). In Thattekad, tree density in teak plantations was comparable with that in forest transects, however, basal area, canopy height, canopy cover, and canopy overlap were all lower than in forest transects. Home gardens, on the other hand, had much higher tree density but lower basal area when compared to buffer or forest transects. They also had high habitat heterogeneity and less canopy height, canopy cover, canopy overlap, and shrub density. In the Anamalai Hills, tea and buffer transects had lower values than forest transects for all variables except habitat heterogeneity.

Principal components analysis of eight vegetation variables extracted two components, PC1 and PC2, which together explained 83.6% of cumulative variance in the dataset with PC1 alone accounting for 69.67 % of variance. PC1 had large positive weightings for basal area (0.858), canopy height (0.942), canopy cover (0.972), canopy overlap (0.971), vertical stratification (0.970), and shrub density (0.630) and a large negative weighting for habitat heterogeneity (-0.819). PC2 had large positive weighting only for tree density (0.963). Eigen values for PC1 and PC2 were

**Table 2**: Comparison of habitat structure in different transects.

| Transect | Tree density (stems/ha) | Basal area (m²/ha) | Canopy height (m) | Canopy cover (%) | Canopy overlap index | Shrub density (stems/plot) | Habitat heterogeneity (% CV) |
|---|---|---|---|---|---|---|---|
| TBA | 466 | 38.78 | 21.68 | 76.53 | 1.4 | 10.85 | 8.41 |
| | (5.9) | (8.04) | (1.2) | (2.1) | (0.1) | (0.9) | |
| TBB | 335.8 | 28.21 | 19.88 | 72.9 | 1.48 | 11.84 | 6.16 |
| | (5.0) | (6.05) | (1.0) | (3.6) | (0.08) | (2.2) | |
| TBC | 334 | 23.84 | 18.08 | 67.35 | 1.2 | 8.24 | 7.32 |
| | (4.9) | (5.97) | (0.9) | (2.8) | (0.08) | (0.8) | |
| TFA | 323 | 40.67 | 19.28 | 79.63 | 1.53 | 10.65 | 9.97 |
| | (4.1) | (8.25) | (1.9) | (3.1) | (0.16) | (1.5) | |
| TFB | 206 | 47.91 | 28.63 | 81.3 | 1.65 | 9.6 | 6.04 |
| | (2.6) | (7.57) | (1.5) | (2.3) | (0.09) | (1.2) | |
| TFC | 366 | 40.58 | 27 | 83.93 | 1.58 | 15.67 | 5.54 |
| | (6.2) | (8.20) | (1.5) | (1.9) | (0.09) | (2.9) | |
| TVA | 2340 | 25.19 | 10.55 | 37.8 | 1.23 | 6.61 | 11.67 |
| | (174.8) | (9.51) | (1.3) | (3.4) | (0.13) | (1.4) | |
| TVB | 2087 | 25.19 | 12.08 | 58.33 | 1.05 | 7.18 | 9.51 |
| | (59.3) | (9.51) | (1.2) | (4.1) | (0.10) | (1.7) | |
| VBA | 278 | 35.62 | 19.8 | 65.38 | 1.2 | 5.8 | 9.91 |
| | (3.5) | (7.07) | (1.9) | (3.4) | (0.11) | (0.8) | |
| VBB | 362 | 42.11 | 20.48 | 51.68 | 1.05 | 4.55 | 10.28 |
| | (4.6) | (13.10) | (2.5) | (3.6) | (0.12) | (0.5) | |
| VBC | 236 | 57.89 | 28.98 | 70.6 | 1.45 | 2.2 | 7.58 |
| | (2.9) | (2.04) | (1.9) | (2.6) | (0.10) | (0.4) | |
| VFA | 668 | 67.61 | 29.25 | 85.2 | 1.63 | 5.95 | 6.85 |
| | (8.5) | (20.15) | (1.9) | (2.9) | (0.09) | (0.8) | |
| VFB | 547 | 52.98 | 26.5 | 82.03 | 1.58 | 7.85 | 7.67 |
| | (6.9) | (9.54) | (2.2) | (3.2) | (0.11) | (0.7) | |
| VFC | 425 | 65.33 | 36.28 | 85.43 | 1.7 | 8.75 | 6.74 |
| | (5.4) | (26.29) | (1.6) | (1.8) | (0.08) | (0.5) | |
| VVA | 72.1 | 6.24 | 2.88 | 10.28 | 0.23 | 2.55 | 11.23 |
| | (0.9) | (2.18) | a(0.9) | (1.5) | (0.07) | (0.2) | |
| VVB | 65.4 | 6.87 | 3.28 | 9.35 | 0.23 | 3.3 | 10.73 |
| | (0.8) | (2.11) | (1.0) | (0.9) | (0.07) | (0.2) | |
| ANOVA results Factor | | | | | | | |
| Site, $F_{1,10}$ | 177.48*** | 1.84 (NS) | 0.01 (NS) | 19.1** | 27.09*** | 23.17** | 1.00 (NS) |
| Strata, $F_{2,10}$ | 92.98*** | 29.8*** | 32.17*** | 77.27*** | 67.29*** | 7.31** | 7.5** |
| Site×Strata, $F_{2,10}$ | 200.05*** | 8.89** | 3.9 (NS) | 11.01** | 19.26*** | 0.43 (NS) | 0.79 (NS) |

The values given in the table are means with standard error in parentheses
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS – non significant

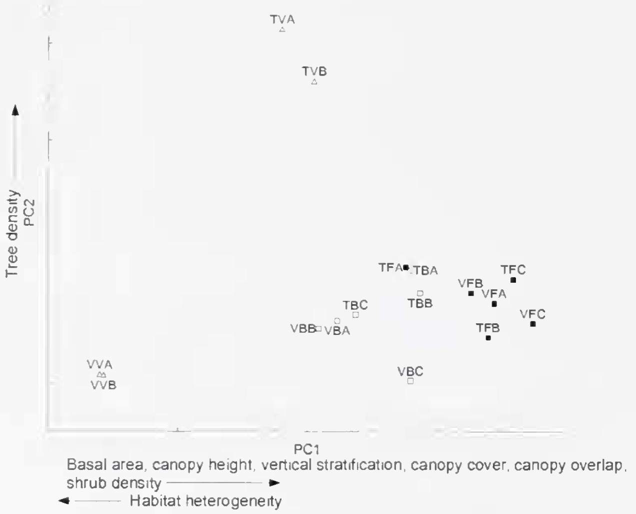


Fig. 2: Ordination of transects on principal component factor axes based on vegetation variables.
Forest, buffer, and village transects are represented by dark-squares, open-squares, and open-triangles, respectively

5.573 and 1.112, respectively. The ordination of transects representing different strata on these two factor scores confirms the above-mentioned trends; the village strata (home gardens in Thattekad and tea plantation transects in Anamalai Hills) lie separated from the rest of the transects representing poor development of foliage, canopy closure, and woody plant density in spite of having highest number of stems per hectare in the case of the Thattekad home gardens (Fig. 2). The forest transects in both sites (with the exception of TFA) have higher scores on PC1 than the buffer transects that occupy intermediate positions between village and forest transects (Fig. 2).

**Bird species richness and density in different land-uses**

A total of 145 bird species and 6,247 individuals were recorded on transects (Appendix). In Thattekad, 122 bird species and 3,210 individuals were recorded with rainforest species constituting 56.6% (69) of all species and 63.4% (2034) of all individuals. In the Anamalai hills, 103 bird species and 3,037 individuals with rainforest species constituting 64.1% (66) of all species and 78.8% (2,394) of all individuals. Rarefaction analysis for Thattekad transects do not show a clear pattern of difference in relation to land-use type for species richness per 200 individuals at confidence interval (CI) of 95%: forest = 49.23 (37-64); buffer = 47.97 (38-60), village = 42.98 (36-51). In the Anamalai Hills, tea transects were poorest in species richness for a comparable sample of 200 individuals at 95% CI: forest = 42.28 (35-50), buffer = 44.74 (35-54), village = 29.38 (27-31).

Bird species density (number of all, rainforest and open-forest species per transect), varied statistically significantly across the three habitat strata mainly because forest and buffer transects had higher values than village transects (Fig. 3, Table 3). The average species density of all birds and open forest birds was higher in Thattekad than the Anamalai Hills, especially in buffer habitats, contributing to statistically significant site effect (Table 3). Interestingly, rainforest bird

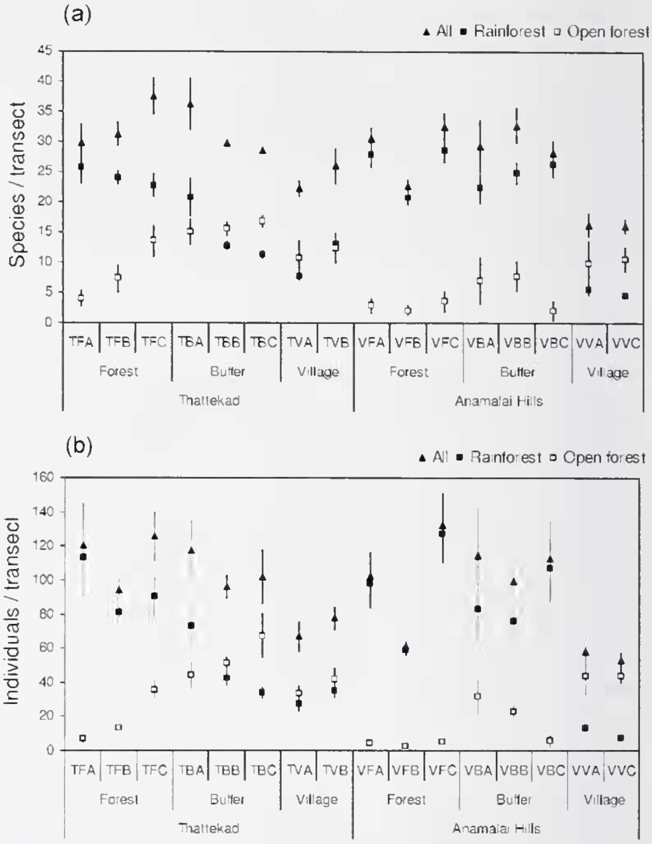


Fig. 3: Species density (a) and abundance (b) of all, rainforest, and open forest bird species, in Thattekad and Anamalai Hills.

**Table 3**: Results of 2-factor analysis of variance of the average bird community structure variables across transects in the study sites

| Variable | Site, $F_{1,10}$ | Strata, $F_{2,10}$ | Site × Strata, $F_{2,10}$ |
|---|---|---|---|
| Bird species density (number of species/transect) | | | |
| All | 5.687* | 12.108** | 0.929 (NS) |
| Rainforest | 1.177 (NS) | 31.195*** | 5.894* |
| Open-forest | 17.664** | 7.259** | 3.388 (NS) |
| Birds abundance (individuals/transect) | | | |
| All | 0.907 (NS) | 7.602* | 0.480 (NS) |
| Rainforest | 0.333 (NS) | 15.366** | 2.723 (NS) |
| Open-forest | 7.009* | 12.666** | 4.478* |

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS – non significant

species density did not differ statistically significantly between sites, but showed a statistically significant interaction between site and strata: it decreased across the habitat gradient from forest to buffer and then village in Thattekad but did not differ substantially between forest and buffer habitats in the Anamalai Hills, although still being lowest in the village transects (Fig. 3a).

Bird species abundance of all, rainforest and open-forest species showed a similar trend as bird species densities (Fig. 3b). Open-forest species showed statistically significant interaction between strata and site. In the Anamalai Hills, open-forest bird abundance was similar in forests and buffers, and higher in village transects, whereas Thattekad had similarly high open-forest bird abundance in buffer and village transects compared to forests. The cardamom transect in the Anamalai Hills (VBC) had higher proportion of rainforest species, as well as individuals in its bird community. In general, forest transects had a greater proportion of rainforest species while open forest species were represented more in buffer and village, especially tea plantation transects.

### Bird species composition in relation to land-use

The MDS ordination in Fig. 4 graphically depicts similarity in bird community composition among sites. Compositional variation appears related to altitude/site (separation between Thattekad transects from Anamalai Hills transects) as well as land-use (village transects occupied extreme, while buffer occupied intermediate positions relative to forest transects in each site). The Anamalai Hills tea plantation transects differed substantially in bird species composition from all the other transects and were similar only to each other. Results of ANOSIM showed statistically significant differences in bird community composition between sites (Global $R = 0.919$, $P = 0.003$) as well as among land-use types (Global $R = 0.918$, $P = 0.001$). Pair-wise comparisons between each pair of habitat strata indicated statistically significant variation between forests and buffer ($R = 0.889$, $P = 0.01$), buffer and village ($R = 0.917$, $P = 0.01$), and forest and village ($R = 1$, $P = 0.01$).

### Changes in flock size, composition, and encounter rate in different land-uses

A total of 101 flocks were recorded (58 complete and 43 incomplete flocks). Of the total 145 species, 82 species (56.6%) participated in flocks at least once. On average, complete flocks contained 9 (±0.56 SE) species and 23.2 (±1.67 SE) individuals, overall. In Thattekad, a mean number of 8.6 (±0.80 SE) species and 22.9 (±2.37) individuals participated in the 29 complete flocks recorded, whereas in the Anamalai Hills, the mean participation was 9.4 (±0.79) species and 23.5 (±2.39) individuals in the 29 complete flocks recorded. Out of 48 rainforest species participating in the flocks, 35 were residents, 7 were endemic residents, and 6 were migrants. In Thattekad, 43 of 63 (68.3%), and in the Anamalai Hills, 45 of 66 (68.2%) rainforest bird species recorded, participated in flocks. Flock encounter rate was higher in the Anamalai Hills (forest = 1.95 flocks/transect; buffer = 2.67 flocks/transect) when compared to Thattekad (forest = 1.59 flocks/transect; buffer = 1.66 flocks/transect). Buffer transects in both sites had higher flock encounter rate than forest transects.

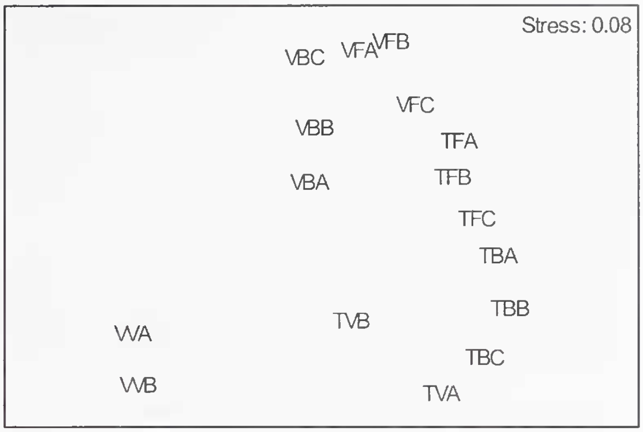

Fig. 4: Variation in bird community composition across transects illustrated by non-metric multidimensional scaling (MDS) ordination. The closer two transects are, the more similar they are in their bird communities

Figure 5 depicts variation in flock size variables across forest and buffer transects in Thattekad and the Anamalai Hills. Rainforest species always contributed more to flock composition than open-forest species in higher altitude site of the Anamalai Hills; but the trend reversed in case of teak plantations in Thattekad showing higher participation of open-forest species and individuals, with TBA being an exception to this. The number of rainforest species in flocks showed statistically significant variation between sites and land-use types (Table 4) with rainforest species participation being higher in forest as compared to buffer transects. Site variation appears primarily due to low representation of rainforest species in flocks in Thattekad buffer transects when compared to Anamalai Hills (Fig. 4). The number of open forest species and individuals in flocks showed primarily a site variation, being higher in Thattekad than Anamalai Hills in comparable land-use types (Table 4, Fig. 5).

### Relationships with vegetation structure

A backward stepwise multiple-regression analysis indicated (Table 5) a statistically significant positive relationship between bird species density (all birds and

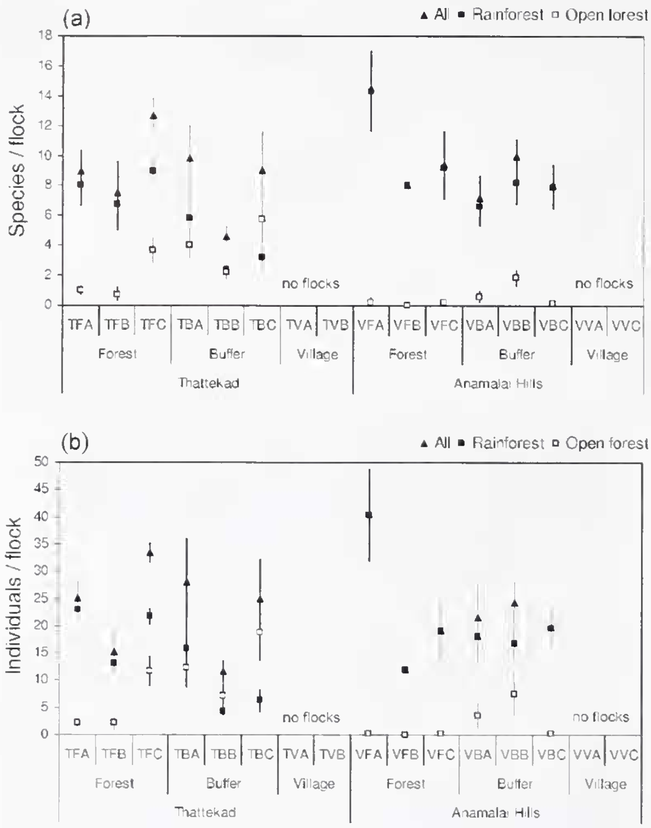


Fig. 5: Number of all, rainforest, and open forest bird species (a) and individuals (b) per complete flock, in Thattekad and Anamalai Hills

rainforest birds) per transect and PC1 which represented canopy variables, vertical foliage structure, basal area, and habitat heterogeneity (negative). Open-forest bird species density showed no statistically significant relationship with either principal component. Abundance of all and rainforest bird species was statistically significantly positively ($P$ = 0.003) related to PC1, while abundance of open-forest species was significantly negatively correlated to PC1 ($P$ = 0.044, Table 5).

Number of rainforest bird species per complete flock showed a highly statistically significant positive relationship with PC1 and a negative relationship with PC2 ($P < 0.037$). Number of individuals of rainforest birds per complete flock was also found to be statistically significantly related to PC1 ($P < 0.005$). Number of open-forest species and individuals per complete flock showed no statistically significant relationship with either PC1 or PC2 (Table 5).

**Table 4**: Results of 2-factor analysis of variance of the average flock structure variables across transects in the study sites

| Variable | Site, $F_{1,8}$ | Strata, $F_{1,8}$ | Site × Strata, $F_{1,8}$ |
|---|---|---|---|
| Flock size (number of species/complete flock) | | | |
| All | 0.235 (NS) | 1.792 (NS) | 0.011 (NS) |
| Rainforest | 7.334* | 9.160* | 0.247 (NS) |
| Open-forest | 10.477* | 3.795 (NS) | 0.995 (NS) |
| Flock abundance (number of individuals/complete flock) | | | |
| All | 0.001 (NS) | 0.199 (NS) | 0.008 (NS) |
| Rainforest | 2.016 (NS) | 2.687 (NS) | 0.242 (NS) |
| Open-forest | 7.810* | 4.661 (NS) | 0.550 (NS) |

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS – non significant

## DISCUSSION

In view of continued threat to bird species from deforestation (Brash 1987; Collar *et al.* 1994; Balmford 1996), many studies have focused on understanding survival of these forest species in human-modified landscapes and the influence of quality of habitat matrix that exists around remaining forest patches (Askins and Philbrick 1987; Stouffer and Bierregaard 1995; Luck and Daily 2003). Similar to earlier studies from tropical forests, the present study found notable changes in bird community structure and composition across different land uses. Flock composition is also known to be affected as a result of changes in habitat, microclimate, and in local bird community (Johns 1986; Thiollay 1995; Stouffer and Bierregaard 1995; Mason 1996; Marsden 1998; Lee *et al.* 2005; Sridhar and Sankar 2008). This is also broadly evidenced in the present study where complex and more developed habitat structure of forests and plantations such as cardamom and coffee with more native shade trees support more rainforest species in bird communities and flocks.

### Habitat structure differences in land-uses

Habitat complexity in terms of vertical foliage profile and structural development was higher in forests when compared with other land-uses. This is supported by other studies where intensification of land-use accompanies structural simplification (Michon and Mary 1990; Garcia-Fernandez and Casado 2005) especially in canopy and understory layers (Greenberg *et al.* 2008), followed by habitat homogeneity (Thiollay 1995; Scales and Marsden 2008). This study finds lower foliage in mid-storey and canopy layers of teak, coffee, and cardamom plantations which show a foliage profile intermediate to forests and villages (tea plantations and home-gardens). Also, cardamom and coffee plantations had lower shrub density as under-storey vegetation was cleared to plant the cash crops (Raman 2006). In general, forests had higher canopy connectivity, tree density, basal area, and shrub density. In non-forest habitats studied, cardamom plantations under native rainforest shade trees provided a habitat structure more similar to rainforests, as reported earlier from studies in the Western Ghats (Raman and Sukumar 2002; Raman 2006). Similarly, coffee plantations under native shade tree species in tropics are known to resemble neighbouring forest structure (Bhagwat *et al.* 2008), and this structural property has potential for biodiversity conservation (Anand *et al.* 2008). Among more intensive forms of land-use, home gardens had more developed habitat structure and vertical distribution of foliage than tea plantations. Home-gardens were mosaics of arecanut palm, coconut palm, jackfruit trees or other crop tree species forming a canopy over densely-planted woody understory (cocoa, coffee), and usually adjoined monocultures of rubber or *Ailanthus malabaricus* with closely planted thin stems (thus accounting for the high tree density but low basal area). Ranganathan *et al.* (2008) studied agricultural systems in Western Ghats of Karnataka similar to home-gardens surveyed in the present study and found arecanut plantations with woody understory to have similar vertical complexity of habitat as managed forests.

Although previous studies examining avian diversity in different land-uses in the Western Ghats have looked at teak, arecanut, cocoa, coffee, and cardamom plantations (Beehler *et al.* 1987; Bhagwat *et al.* 2005; Raman 2006; Anand *et al.* 2008; Ranganathan *et al.* 2008), there are no published reports on habitat structure and avian conservation values of tea plantations. Tea plantations are a major form of land-use in the Western Ghats accounting for over 119,000 ha, having increased by 6,200 ha (5.5%) in the period 2000-2006 (Mudappa and Raman 2007; Tea Board Statistics, http://www.teaboard.gov.in). These plantations are dense monocultures of tea bushes with sparse canopy of a single alien tree species planted in rows (silver oak *Grevillea robusta*, native to Australia) at 12 m spacing. The higher habitat heterogeneity of tea plantations can be attributed to the variability induced by large tracts of tea shrubs maintained at a uniform height of about a metre and with no foliage at all in higher vertical classes alternating with points with more foliage directly below silver oak trees. Tea plantations are intensively managed year-round with cycles of agro-chemical application, pruning, and harvest of leaves. In relation to other plantations studied thus far in the Western Ghats, the results of this study indicate that tea plantations are the most extreme in terms of alteration of habitat relative to rainforests.

**Changes in bird community and composition**

We found more bird species and individuals in the lower altitude site of Thattekad than in the higher altitude site of the Anamalai Hills. Thattekad teak buffers supported more open-forest species and individuals, leading to statistically significant differences between sites. When we looked at similarity of bird community composition across strata in both altitudes, we found bird communities to be more similar within a given site/altitude than across. The effect of habitat modification was apparent as bird community differed between land-use types at both the sites.

Looking at bird community composition represented

**Table 5**: Relationships between bird community and flock variables with habitat components (PC1 and PC2) taken as independent variables in backward stepwise multiple regression analysis

| | Standardized regression coefficient, Beta (*P*) | | | | | |
|---|---|---|---|---|---|---|
| Dependent variable | PC1 | PC2 | $R^2$ | *F* | *df* | *P* |
| *Total bird species per transect* | | | | | | |
| All | 0.786 (0.000) | - | 0.619 | 22.7 | 1, 14 | 0.000 |
| Rainforest species per transect | 0.803 (0.000) | - | 0.645 | 25.43 | 1, 14 | 0.000 |
| Open-forest species per transect | - | - | - | - | - | - |
| *Total individuals per transect* | | | | | | |
| All | 0.692 (0.003) | - | 0.479 | 12.86 | 1, 14 | 0.003 |
| Rainforest individuals per transect | 0.773 (0.000) | - | 0.597 | 20.78 | 1, 14 | 0.000 |
| Open-forest individuals per transect | -0.508 (0.044) | - | 0.258 | 4.878 | 1, 14 | 0.044 |
| *Species per complete flock* | | | | | | |
| Rainforest species per flock | 0.761 (0.000) | -0.352 (0.037) | 0.657 | 15.356 | 2, 13 | 0.000 |
| Open-forest species per flock | - | - | - | - | - | |
| *Individuals per flock* | | | | | | |
| Rainforest individuals per flock | 0.698 (0.005) | - | 0.407 | 11.27 | 1, 14 | 0.005 |
| Open-forest individuals per flock | - | - | - | - | - | - |

by rainforest bird species versus open-forest bird species, the number of rainforest species and individuals decreased along the habitat gradient from forest to buffer and then villages. Teak plantations of Thattekad, in general, had more open-forest species and thus seem to support fewer rainforest species when compared to coffee and cardamom plantations of the Anamalai Hills. Among the non-forest habitats, cardamom plantation appears to be the best kind of land-use in its ability to support rainforest species and discouraging open-forest species.

The overall species richness and abundance did not vary much between forests and buffers but the composition of bird community was different as species characteristic of primary and mature forests get replaced by species of disturbed or open-forests (Daniels *et al.* 1990; Estrada *et al.* 1997; Lawton *et al.* 1998; Raman 2001; Lindell *et al.* 2004; Waltert *et al.* 2005; Harvey and Villalobos 2007). Bhagwat *et al.* (2008), in a literature review, compared agrosystems (such as coffee, cocoa, forest rubber, and banana plantations) with forest and found high species richness (92%) compared to forests while lower similarity (52%, Jaccard index) with forest community. Raman (2006) in an earlier study in the southern Western Ghats found that only 59-67% of species present in shade coffee plantations were rainforest species, the balance being species of more open habitats. In another study from the Western Ghats, Ranganathan *et al.* (2008) found arecanut plantations to retain 90% of bird species that were also found associated with regional forests.

Individual bird species may show varying responses to different land-use systems. In Thattekad, open-forest species such as Southern Coucal *Centropus [sinensis] parroti*, Oriental Magpie-robin *Copsychus saularis*, Red-whiskered Bulbul *Pycnonotus jocosus*, and Rufous Treepie *Dendrocitta vagabunda* were found to be more abundant in teak buffers and home-gardens than in forests. The Jungle Babbler *Turdoides striata*, another open-forest species, was found only in teak plantations. Rainforest species such as Malabar Barbet *Megalaima malabarica*, Flame-throated Bulbul *Pycnonotus gularis*, and Yellow-browed Bulbul *Iole indica* decreased in abundance from forest to buffer and than villages. The Grey-headed Bulbul *Pycnonotus priocephalus*, a rainforest species endemic to Western Ghats, and the Malabar Trogon *Harpactes fasciatus* was found only in forests. Lesser Hill Myna *Gracula indica*, Greater Racket-tailed Drongo *Dicrurus paradiseus*, and White-cheeked Barbet *Megalaima viridis* were the rainforest species found to be common throughout, irrespective of the land-use type. In the Anamalai Hills, Red-whiskered Bulbul, Oriental Magpie-Robin, Common Tailorbird *Orthotomus sutorius*, Indian Jungle Crow *Corvus [macrorhynchos] culminatus*, Rufous-backed Long-tailed Shrike *Lanius schach erythronotus*, and Chestnut-headed Bee-eater *Merops leschenaulti*, along with an open-forest migrant Blyth's Reed-warbler *Acrocephalus dumetorum*, were found to be more common in tea plantations. They were less frequent or absent in buffer habitats and forests. Rainforest species such as Asian Fairy Bluebird *Irena puella*, Brown-cheeked Fulvetta *Alcippe poioicephala*, and Yellow-browed Bulbul along with two rainforest migrants, Large-billed Leaf-warbler *Phylloscopus magnirostris*, and Rusty-tailed Flycatcher *Muscicapa ruficauda*, decreased in abundance from forest to buffer and were never found in tea plantations. One rainforest species, Indian Scimitar Babbler *Pomatorhinus [schisticeps] horsfieldii*, was found to be more common in tea plantations than in coffee, cardamom or forests. Small Sunbird *Leptocoma minima*, a Western Ghats endemic, preferred forests and buffers over tea plantations.

**Differences in flock size, composition, and encounter rate**

Participation of species in flocks was observed to be lower than that found in an earlier study in the southern Western Ghats where 87 out of 109 species participated in flocks (Sridhar and Sankar 2008). The previous study compared forest fragments of different sizes, whereas we sampled on more open roads or dirt tracks leading to more open-forest species and a greater number of species recorded outside of flocks. Flock size overall did not seem to be affected considerably by land-use although other studies suggest that overall species participation in flocks decreases with habitat degradation and changes in bird community (Bierregaard and Lovejoy 1989; Maldonado-Coelho and Marini 2004; Lee *et al.* 2005; Sridhar and Sankar 2008). The number of rainforest species that participated in flocks, however, did vary significantly by land-use in our study. Rainforest species, in general, contributed more to the flocks than open-forest species, which could explain the near absence of flocks from heavily-modified habitats such as tea and home-gardens, which support very low number of rainforest species and a higher proportion of open-forest species in their bird community. As flocks are species-rich (and, in some Neotropical areas, even hold interspecific territories), they may be vulnerable to changes in habitat structure, microclimate, and bird community (Munn and Terborgh 1979; Bierregaard and Lovejoy 1989; Thiollay 1992; Hutto 1994; Jullien and Thiollay 1998; Stratford and Stouffer 1999). Flocks can therefore be used as indicators of disturbance (Maldonado-Coelho and Marini 2004) with the number of rainforest versus open-forest species taken as a measure of the ability of particular land-use type to support the complex interactions that lead to formation of flocks.

Flock encounter rate was found to be much higher in the higher altitude site. Buffer transects in both altitudes showed higher flock encounter rate than the forests. This may possibly be due to better visibility in the buffer plantations that had more open habitat relative to forest (particularly in mid-storey layers). Another reason for this could be the higher visibility for predators (e.g., raptors) as well and therefore an increased tendency of bird species to occur in flocks (Thiollay 1999). A flock was usually sighted shortly before or soon after hearing or sighting a raptor species (S. Sidhu, unpublished data).

**Effect of habitat modification on bird community and flocks**

Bird community and flock composition were observed to differ with land-use and seem to be affected by habitat alterations. Among different land-uses, tea plantations turned out to be the poorest in habitat structural complexity, which was reflected in their highly altered bird community composition and complete absence of flocks. The home-gardens surveyed in the present study also had poorer habitat complexity. When compared to TVA, the other home garden (TVB) was found to support more rainforest species and two incomplete flocks were observed. This difference in bird composition between similar land-uses could be due to the latter site being located in a small tribal village surrounded on all sides by forest.

Structural complexity and similarity with forest habitat were seen to positively influence rainforest birds in the community and flocks. Cardamom, coffee, and teak plantations seem to hold more species than severely modified land-use represented by tea plantations and home gardens. When comparing among different buffer habitats, cardamom and coffee fared better than teak in supporting a greater proportion of the respective rainforest species at that altitude. This is supported by studies showing that more forest species can be supported by a mix of cultivated and native shade trees (Taylor *et al.* 1993; Thiollay 1995; Greenberg *et al.* 1997; Powell and Bjork 2004; Sekercioglu *et al.* 2006). Beehler *et al.* (1987) in an earlier study in Eastern Ghats, India, found teak monoculture to be a poor habitat for birds. TBA was the only teak buffer showing higher rainforest bird species in flocks. It had patches of relatively undisturbed rainforests interrupting the plantation. These forest patches are necessary as they act as refuges for species that are sensitive to changes in land-use (Sekercioglu *et al.* 2006). In a study by Faria *et al.* (2000) from Brazil that compared bird communities in a landscape dominated by natural forest (<6% under cocoa plantation) with a landscape dominated by cocoa plantations, bird communities were found to be richer in the former landscape indicating the landscape-level influence of forest cover and proximity.

Many studies have reported the importance of natural shade trees in coffee and cardamom as they support greater number of forest bird species (Estrada *et al.* 1997; Mudappa and Raman 2007; Sodhi *et al.* 2008). Beehler *et al.* (1987) also observed that coffee plantations with companion tracts of remnant forest maintain healthy population of birds. Similarly, the coffee plantations we sampled had interspersed forest fragments and native shade trees along with exotic ones and this supports more rainforest species which then participate in flocks. Anand *et al.* (2008) observed bird species richness and abundance in coffee plantations to increase with increase in basal area of native tree species and decline with increasing distance from contiguous forest. Thus, at landscape level, plantations with native shade trees and forest fragments are extremely important to retain as they act as a support system for sensitive species and provide better connectivity between different land-uses. Planting more native tree species in these plantations and restoring the degraded forest fragments will add to value of the habitat. Habitat managements must discourage further conversion of these into monocultures or their extreme modification into tea plantations.

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**Appendix 1**: List of bird species, codes, and average relative abundance (abundance of a species / abundance of all species, represented as percentage for a transect) in the three main habitat strata across the two study sites (Thattekad and Anamalai Hills)

| Common names | Scientific name | Codes | Thattekad | | | Anamalai Hills | | |
|---|---|---|---|---|---|---|---|---|
| | | | Forest | Buffer | Village | Forest | Buffer | Village |
| Asian Brown Flycatcher | *Muscicapa dauurica** | OF/M | 0.13 | 0.00 | 0.32 | 0.00 | 0.40 | 0.00 |
| Blue-headed Rock-thrush | *Monticola cinclorhynchus** | OF/M | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.23 |
| Black-naped Oriole | *Oriolus chinensis** | OF/M | 0.28 | 0.77 | 0.00 | 0.07 | 0.16 | 0.00 |
| Brown Shrike | *Lanius cristatus* | OF/M | 0.00 | 0.00 | 0.16 | 0.06 | 0.07 | 0.00 |
| Blyth's Reed-warbler | *Acrocephalus dumetorum* | OF/M | 0.06 | 0.33 | 0.16 | 0.72 | 1.40 | 14.42 |
| Blue-throated Flycatcher | *Cyornis rubeculoides* | OF/M | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| Common Rosefinch | *Carpodacus erythrinus** | OF/M | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 0.00 |
| European Golden Oriole | *Oriolus oriolus** | OF/M | 0.27 | 0.32 | 2.50 | 0.06 | 0.00 | 0.00 |
| Asian Koel | *Eudynamys scolopaceus* | OF/R | 0.19 | 0.58 | 0.91 | 0.00 | 0.00 | 0.00 |
| Ashy Prinia | *Prinia socialis* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 |
| Ashy Woodswallow | *Artamus fuscus* | OF/R | 0.06 | 0.41 | 2.12 | 0.00 | 0.00 | 0.00 |
| Indian Pygmy Woodpecker | *Dendrocopos nanus** | OF/R | 0.64 | 0.67 | 0.37 | 0.13 | 0.30 | 0.00 |
| Blue-faced Malkoha | *Phaenicophaeus viridirostris** | OF/R | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| Brown Fish-owl | *Ketupa zeylonensis* | OF/R | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black-hooded Oriole | *Oriolus xanthornus** | OF/R | 0.52 | 4.32 | 0.56 | 0.00 | 0.00 | 0.00 |
| Black-rumped Flameback | *Dinopium benghalense** | OF/R | 0.61 | 1.59 | 1.90 | 0.07 | 0.08 | 0.47 |
| Brahminy Kite | *Haliastur indus* | OF/R | 0.13 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Blue-winged Leafbird | *Chloropsis cochinchinensis** | OF/R | 0.16 | 0.32 | 0.32 | 0.00 | 0.00 | 0.00 |
| Chestnut-headed Bee-eater | *Merops leschenaulti* | OF/R | 0.13 | 0.74 | 0.00 | 0.33 | 0.51 | 6.49 |
| Common Hawk Cuckoo | *Hierococcyx varius** | OF/R | 0.07 | 1.78 | 1.61 | 0.00 | 0.00 | 0.00 |
| Coppersmith Barbet | *Megalaima haemacephala** | OF/R | 0.63 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Common Hoopoe | *Upupa epops* | OF/R | 0.06 | 0.07 | 0.00 | 0.00 | 0.00 | 0.21 |
| Common Iora | *Aegithina tiphia** | OF/R | 0.60 | 0.23 | 0.00 | 0.07 | 0.17 | 0.00 |
| Common Kestrel | *Falco tinnunculus* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 |
| Common Myna | *Acridotheres tristis** | OF/R | 0.48 | 2.12 | 3.49 | 0.00 | 0.15 | 1.29 |
| Common Tailorbird | *Orthotomus sutorius** | OF/R | 0.18 | 0.73 | 1.45 | 0.00 | 1.20 | 3.45 |
| Common Woodshrike | *Tephrodornis pondicerianus** | OF/R | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Crested Treeswift | *Hemiprocne coronata* | OF/R | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 |
| Indian Scops-owl | *Otus bakkamoena* | OF/R | 0.07 | 0.08 | 0.00 | 0.06 | 0.07 | 0.00 |
| Grey-headed Starling | *Sturnia malabarica** | OF/R | 1.67 | 0.52 | 0.48 | 0.00 | 0.07 | 0.00 |
| Grey-bellied Cuckoo | *Cacomantis passerinus* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 |
| Greater Coucal | *Centropus sinensis** | OF/R | 1.26 | 2.69 | 4.61 | 0.53 | 0.16 | 4.04 |
| Great Tit | *Parus major** | OF/R | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 |
| House Sparrow | *Passer domesticus* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Indian Cuckoo | *Cuculus micropterus* | OF/R | 0.06 | 1.37 | 0.00 | 0.00 | 0.00 | 0.00 |
| Jungle Babbler | *Turdoides striata** | OF/R | 0.65 | 14.16 | 1.02 | 0.00 | 0.00 | 0.00 |
| Jungle Myna | *Acridotheres fuscus** | OF/R | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 |
| Jungle Owlet | *Glaucidium radiatum** | OF/R | 0.06 | 0.78 | 0.00 | 0.06 | 0.00 | 0.00 |
| Indian Jungle Crow | *Corvus (macrorhynchos) culminatus** | OF/R | 1.27 | 3.17 | 12.14 | 1.20 | 0.99 | 7.04 |
| Loten's Sunbird | *Cinnyris lotenius** | OF/R | 0.15 | 0.08 | 0.67 | 0.00 | 0.00 | 0.00 |
| Long-tailed Shrike | *Lanius schach* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.40 |
| Mottled Wood-owl | *Strix ocellata* | OF/R | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.00 |
| Oriental Magpie-robin | *Copsychus saularis** | OF/R | 0.06 | 1.77 | 3.08 | 0.06 | 0.52 | 6.46 |
| Plum-headed Parakeet | *Psittacula cyanocephala** | OF/R | 1.09 | 0.97 | 0.32 | 0.00 | 0.76 | 0.21 |
| Pied Bushchat | *Saxicola caprata* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.48 |
| Plain Prinia | *Prinia inornata* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Purple-rumped Sunbird | *Leptocoma zeylonica** | OF/R | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 | 0.00 |
| Purple Sunbird | *Cinnyris asiaticus** | OF/R | 0.00 | 0.00 | 0.97 | 0.14 | 0.16 | 0.23 |
| Rock Pigeon | *Columba livia* | OF/R | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rose-ringed Parakeet | *Psittacula krameri* | OF/R | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rufous Treepie | *Dendrocitta vagabunda** | OF/R | 1.00 | 4.56 | 3.75 | 0.00 | 0.00 | 0.00 |

**Appendix 1**: List of bird species, codes, and average relative abundance (abundance of a species / abundance of all species, represented as percentage for a transect) in the three main habitat strata across the two study sites (Thattekad and Anamalai Hills) (*contd.*)

| Common names | Scientific name | Codes | Thattekad | | | Anamalai Hills | | |
|---|---|---|---|---|---|---|---|---|
| | | | Forest | Buffer | Village | Forest | Buffer | Village |
| Red-vented Bulbul | *Pycnonotus cafer** | OF/R | 0.00 | 0.35 | 0.81 | 0.00 | 0.00 | 0.00 |
| Red-whiskered Bulbul | *Pycnonotus jocosus** | OF/R | 0.57 | 2.00 | 4.30 | 0.44 | 9.38 | 22.10 |
| Red-wattled Lapwing | *Vanellus indicus* | OF/R | 0.06 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 |
| Stork-billed Kingfisher | *Pelargopsis capensis* | OF/R | 0.00 | 0.26 | 0.35 | 0.00 | 0.00 | 0.00 |
| Shikra | *Accipiter badius* | OF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| Small Minivet | *Pericrocotus cinnamomeus** | OF/R | 0.98 | 0.00 | 0.97 | 0.00 | 0.00 | 0.00 |
| Spotted Dove | *Streptopelia chinensis* | OF/R | 0.22 | 0.40 | 0.56 | 0.13 | 0.85 | 2.42 |
| Streak-throated Woodpecker | *Picus xanthopygaeus** | OF/R | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.23 |
| Tickell's Blue Flycatcher | *Cyornis tickelliae* | OF/R | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 |
| White-breasted Waterhen | *Amaurornis phoenicurus* | OF/R | 0.00 | 0.32 | 0.56 | 0.00 | 0.00 | 0.47 |
| White-throated Kingfisher | *Halcyon smyrnensis* | OF/R | 0.54 | 1.75 | 1.05 | 0.00 | 0.15 | 0.23 |
| Yellow-footed Green-pigeon | *Treron phoenicopterus* | OF/R | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Small Sunbird | *Leptocoma minima** | RF/E | 2.02 | 0.44 | 1.61 | 11.28 | 6.23 | 0.23 |
| Grey-headed Bulbul | *Pycnonotus priocephalus** | RF/E | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Malabar Parakeet | *Psittacula columboides** | RF/E | 1.41 | 0.78 | 1.77 | 1.20 | 2.98 | 0.00 |
| Malabar Grey Hornbill | *Ocyceros griseus** | RF/E | 4.52 | 2.45 | 1.69 | 2.98 | 1.94 | 0.45 |
| Nilgiri Flycatcher | *Eumyias albicaudatus** | RF/E | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Indian Rufous Babbler | *Turdoides subrufa* | RF/E | 0.18 | 0.00 | 0.00 | 0.14 | 0.29 | 0.70 |
| Ceylon Frogmouth | *Batrachostomus moniliger* | RF/E | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| White-bellied Blue Flycatcher | *Cyornis pallipes** | RF/E | 0.88 | 0.14 | 0.00 | 0.39 | 0.00 | 0.00 |
| White-bellied Treepie | *Dendrocitta leucogastra** | RF/E | 0.00 | 0.43 | 0.00 | 1.24 | 0.29 | 0.00 |
| Ashy Drongo | *Dicrurus leucophaeus** | RF/M | 0.39 | 0.31 | 0.65 | 0.20 | 0.22 | 0.00 |
| Brown-breasted Flycatcher | *Muscicapa muttui* | RF/M | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Forest Wagtail | *Dendronanthus indicus* | RF/M | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 |
| Greenish Warbler | *Phylloscopus trochiloides** | RF/M | 2.30 | 2.77 | 3.43 | 2.49 | 4.54 | 2.23 |
| Grey Wagtail | *Motacilla cinerea* | RF/M | 0.00 | 0.00 | 0.00 | 0.32 | 0.15 | 0.21 |
| Indian Blue Robin | *Luscinia brunnea* | RF/M | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Large-billed Leaf-warbler | *Phylloscopus magnirostris** | RF/M | 1.61 | 0.29 | 0.00 | 4.29 | 0.69 | 0.00 |
| Rusty-tailed Flycatcher | *Muscicapa ruficauda** | RF/M | 0.16 | 0.00 | 0.00 | 1.19 | 0.23 | 0.00 |
| Verditer Flycatcher | *Eumyias thalassinus** | RF/M | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Western Crowned Warbler | *Phylloscopus occipitalis** | RF/M | 0.00 | 0.00 | 0.00 | 1.75 | 4.05 | 0.00 |
| Asian Fairy-bluebird | *Irena puella** | RF/R | 3.15 | 0.99 | 1.34 | 6.50 | 1.98 | 0.00 |
| Asian Paradise Flycatcher | *Terpsiphone paradisi** | RF/R | 0.42 | 0.08 | 0.00 | 0.26 | 0.17 | 0.00 |
| Blue-bearded Bee-eater | *Nyctyornis athertoni* | RF/R | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| Black-capped Bulbul | *Pycnonotus melanicterus** | RF/R | 4.09 | 1.59 | 0.16 | 1.75 | 0.31 | 0.00 |
| Brown-cheeked Fulvetta | *Alcippe poioicephala** | RF/R | 2.58 | 0.07 | 0.00 | 5.16 | 1.18 | 0.00 |
| Besra Sparrowhawk | *Accipiter virgatus* | RF/R | 0.00 | 0.00 | 0.00 | 0.06 | 0.08 | 0.00 |
| Hume's Hawk-owl | *Ninox obscura* | RF/R | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.00 |
| Black Baza | *Aviceda leuphotes* | RF/R | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| Himalayan Black Bulbul | *Hypsipetes leucocephalus** | RF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 |
| Black Eagle | *Ictinaetus malayensis* | RF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 |
| Black-lored Yellow Tit | *Parus xanthogenys** | RF/R | 0.44 | 0.00 | 0.00 | 0.84 | 1.21 | 0.21 |
| Black-naped Blue Monarch | *Hypothymis azurea** | RF/R | 0.90 | 0.21 | 0.00 | 0.26 | 0.25 | 0.00 |
| Bronzed Drongo | *Dicrurus aeneus** | RF/R | 1.79 | 3.53 | 1.05 | 1.93 | 1.79 | 0.00 |
| Pied Flycatcher-shrike | *Hemipus picatus** | RF/R | 0.09 | 0.07 | 0.16 | 0.32 | 0.94 | 0.00 |
| Ceylon Small Barbet | *Megalaima rubricapillus** | RF/R | 4.52 | 0.42 | 1.21 | 0.58 | 1.39 | 0.21 |
| Common Flameback | *Dinopium javanense** | RF/R | 0.00 | 0.33 | 0.00 | 1.71 | 1.31 | 0.23 |
| Crested Goshawk | *Accipiter trivirgatus* | RF/R | 0.00 | 0.07 | 0.00 | 0.19 | 0.17 | 0.00 |
| Crested Serpent-eagle | *Spilornis cheela* | RF/R | 0.31 | 0.28 | 0.16 | 0.79 | 1.39 | 1.07 |
| Dark-fronted Babbler | *Rhopocichla atriceps** | RF/R | 4.00 | 0.00 | 0.00 | 3.00 | 2.00 | 0.00 |
| Dollarbird | *Eurystomus orientalis** | RF/R | 0.14 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 |
| Square-tailed Drongo-cuckoo | *Surniculus lugubris* | RF/R | 0.07 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 |
| Emerald Dove | *Chalcophaps indica** | RF/R | 0.14 | 0.37 | 0.00 | 0.46 | 0.16 | 0.00 |

**Appendix 1**: List of bird species, codes, and average relative abundance (abundance of a species / abundance of all species, represented as percentage for a transect) in the three main habitat strata across the two study sites (Thattekad and Anamalai Hills) (*contd.*)

| Common names | Scientific name | Codes | Thattekad | | | Anamalai Hills | | |
|---|---|---|---|---|---|---|---|---|
| | | | Forest | Buffer | Village | Forest | Buffer | Village |
| Gold-fronted Leafbird | *Chloropsis aurifrons** | RF/R | 1.14 | 0.84 | 0.00 | 0.47 | 1.94 | 0.00 |
| Grey-headed Canary-flycatcher | *Culicicapa ceylonensis** | RF/R | 0.09 | 0.07 | 0.16 | 1.59 | 1.48 | 0.00 |
| Grey-headed Fish-eagle | *Ichthyophaga ichthyaetus* | RF/R | 0.00 | 0.00 | 0.00 | 1.19 | 0.00 | 0.00 |
| Green Imperial-pigeon | *Ducula aenea* | RF/R | 2.67 | 0.80 | 0.81 | 0.25 | 0.00 | 0.00 |
| Greater Flameback | *Chrysocolaptes lucidus** | RF/R | 1.68 | 0.53 | 0.70 | 0.79 | 0.92 | 0.00 |
| Great Pied Hornbill | *Buceros bicornis* | RF/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 |
| Grey Junglefowl | *Gallus sonneratii* | RF/R | 1.25 | 1.89 | 0.56 | 0.58 | 0.46 | 0.21 |
| Greater Racket-tailed Drongo | *Dicrurus paradiseus** | RF/R | 10.18 | 10.14 | 7.77 | 5.40 | 2.29 | 0.00 |
| Common Hill-Myna | *Gracula religiosa** | RF/R | 5.86 | 2.45 | 3.23 | 4.23 | 2.37 | 0.21 |
| Heart-spotted Woodpecker | *Hemicircus canente** | RF/R | 1.09 | 0.26 | 0.00 | 0.07 | 0.39 | 0.00 |
| Indian Scimitar-babbler | *Pomatorhinus (schisticeps) horsfieldii** | RF/R | 0.00 | 0.00 | 0.00 | 1.10 | 1.52 | 5.76 |
| Large Woodshrike | *Tephrodornis gularis** | RF/R | 0.16 | 1.00 | 0.00 | 1.26 | 1.33 | 0.00 |
| Lesser Yellownape | *Picus chlorolophus** | RF/R | 0.69 | 0.48 | 0.35 | 0.13 | 0.08 | 0.00 |
| Little Spiderhunter | *Arachnothera longirostra** | RF/R | 2.23 | 0.14 | 0.65 | 1.36 | 0.23 | 0.00 |
| Malabar Trogon | *Harpactes fasciatus** | RF/R | 0.42 | 0.00 | 0.00 | 0.79 | 0.00 | 0.00 |
| Mountain Imperial-pigeon | *Ducula badia* | RF/R | 0.95 | 0.07 | 0.00 | 2.25 | 1.97 | 0.23 |
| Malabar Whistling-thrush | *Myophonus horsfieldii* | RF/R | 0.84 | 0.24 | 0.00 | 3.13 | 1.20 | 1.99 |
| Oriental Honey-buzzard | *Pernis ptilorhyncus* | RF/R | 0.07 | 0.17 | 0.00 | 0.06 | 0.00 | 0.00 |
| Orange-headed Thrush | *Zoothera citrina** | RF/R | 0.06 | 0.21 | 0.00 | 0.00 | 0.22 | 0.00 |
| Oriental White-eye | *Zosterops palpebrosus** | RF/R | 0.00 | 0.00 | 0.16 | 0.97 | 3.00 | 0.00 |
| Ceylon Green-pigeon | *Treron pompadora* | RF/R | 0.73 | 0.14 | 0.00 | 0.00 | 0.65 | 0.00 |
| Nilgiri Flowerpecker | *Dicaeum concolor** | RF/R | 3.01 | 2.26 | 1.96 | 3.46 | 4.15 | 0.23 |
| Puff-throated Babbler | *Pellorneum ruficeps* | RF/R | 0.19 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 |
| Red Spurfowl | *Galloperdix spadicea* | RF/R | 0.06 | 0.07 | 0.00 | 0.00 | 0.15 | 0.21 |
| Rufous Woodpecker | *Micropternus brachyurus** | RF/R | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Orange Minivet | *Pericrocotus flammeus** | RF/R | 1.67 | 0.00 | 1.61 | 2.26 | 5.54 | 0.00 |
| Speckled Piculet | *Picumnus innominatus** | RF/R | 0.13 | 0.00 | 0.00 | 0.07 | 0.42 | 0.00 |
| Velvet-fronted Nuthatch | *Sitta frontalis** | RF/R | 0.26 | 0.00 | 0.00 | 1.09 | 1.56 | 0.00 |
| Vernal Hanging-parrot | *Loriculus vernalis** | RF/R | 4.42 | 2.24 | 2.85 | 2.54 | 2.27 | 0.00 |
| White-bellied Woodpecker | *Dryocopus javensis* | RF/R | 0.06 | 0.08 | 0.00 | 0.14 | 0.00 | 0.00 |
| White-cheeked Barbet | *Megalaima viridis** | RF/R | 6.49 | 5.89 | 6.91 | 4.93 | 6.79 | 4.22 |
| Yellow-browed Bulbul | *Iole indica** | RF/R | 3.43 | 0.44 | 1.37 | 6.38 | 4.88 | 0.00 |
| Whiskered Tern | *Chlidonias hybrida* | WB/M | 0.26 | 0.09 | 0.19 | 0.00 | 0.00 | 0.00 |
| Bronze-winged Jacana | *Metopidius indicus* | WB/R | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 |
| Oriental Darter | *Anhinga melanogaster* | WB/R | 0.00 | 0.17 | 0.75 | 0.00 | 0.00 | 0.00 |
| Great Egret | *Egretta alba* | WB/R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 |
| Intermediate Egret | *Egretta intermedia* | WB/R | 0.06 | 0.00 | 1.45 | 0.00 | 0.00 | 0.00 |
| Indian Pond-heron | *Ardeola grayii* | WB/R | 0.00 | 0.15 | 1.63 | 0.00 | 0.08 | 1.84 |
| Little Cormorant | *Phalacrocorax niger* | WB/R | 0.06 | 0.34 | 0.56 | 0.00 | 0.00 | 0.00 |
| Lesser Whistling-duck | *Dendrocygna javanica* | WB/R | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.00 |
| River Tern | *Sterna aurantia* | WB/R | 0.32 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total number of individuals | | | 1372 | 1261 | 577 | 1286 | 1305 | 446 |

* Flocking species

Codes: OF=Open-forest species, RF=Rainforest species, WB=Water-birds, R=Resident, E=Endemic, M=Migrant

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